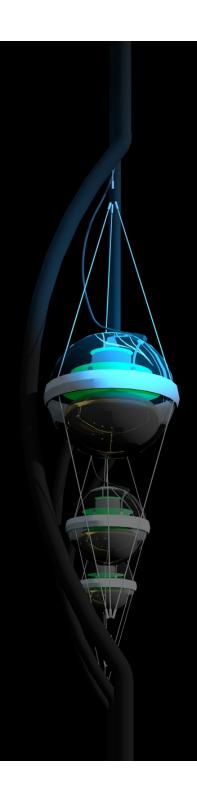


snowmass 2013

- IceCube
- atmospheric and cosmic neutrinos
- the search for dark matter



all results with detector under construction

• soon:

→ results from completed detector with improved software and calibration

→ WIMP masses as low as 10 GeV

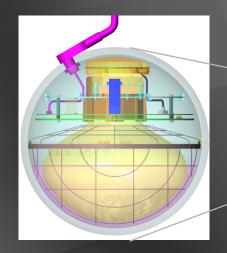
far from the square root regime

• thanks: C. Rott, D. Grant and M. Danninger

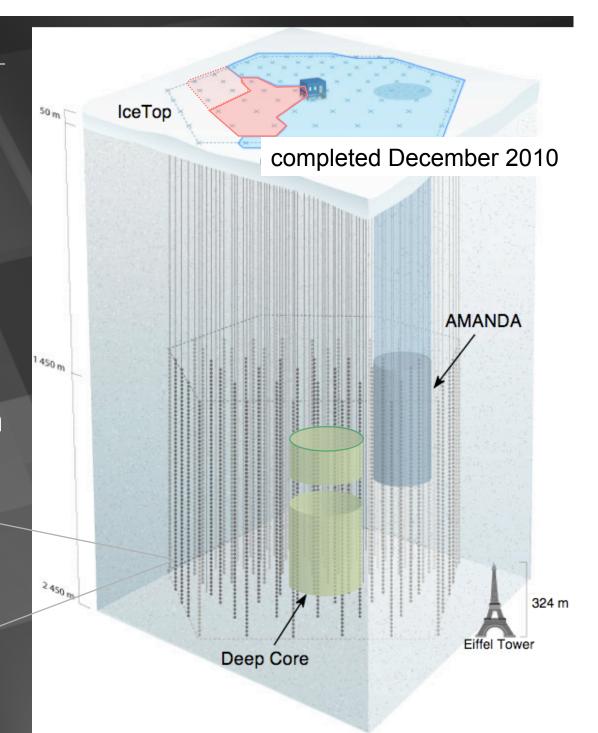
shielded and optically transparent medium CC **Charged Current** lattice of photomultipliers

IceCube / Deep Core

- 5160 optical sensors between 1.5 ~ 2.5 km
- 10 GeV to infinity
- < 0.5 degree on-line
 - < 0.2 degree off line
- < 15% energy resolution



Digital Optical Module (DOM)



muons detected per year:

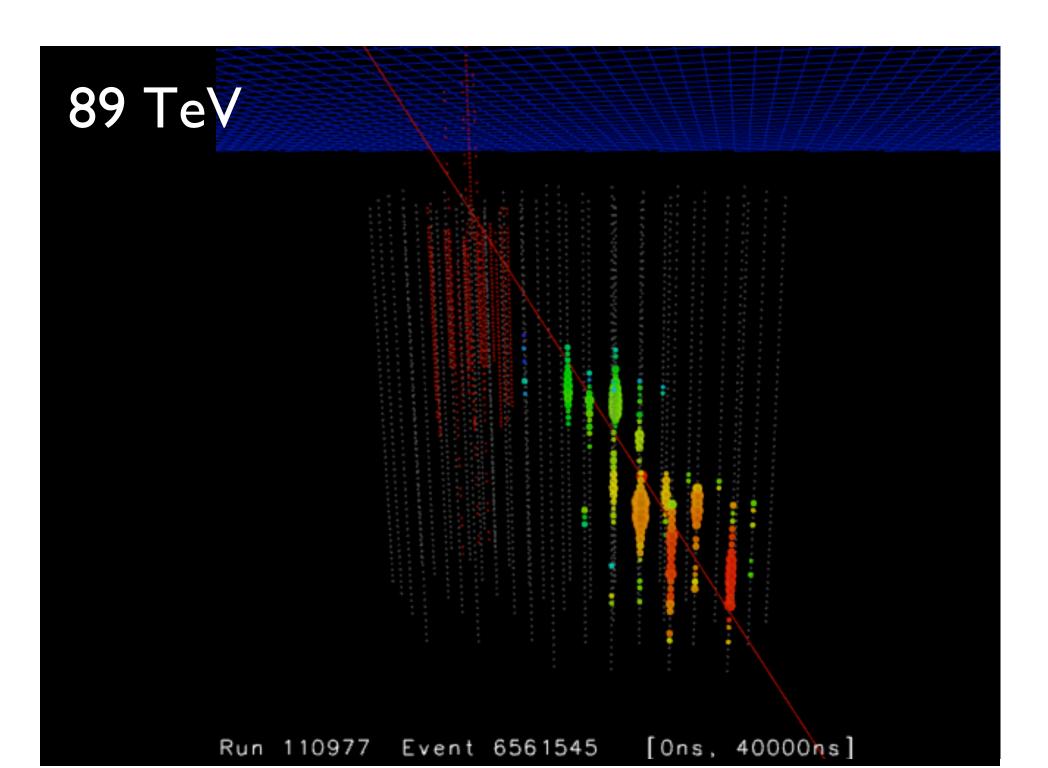
• atmospheric*
$$\mu$$
 ~ 10¹¹

• atmospheric**
$$\nu \rightarrow \mu$$
 ~ 10⁵

• cosmic
$$v \rightarrow \mu \sim 10$$

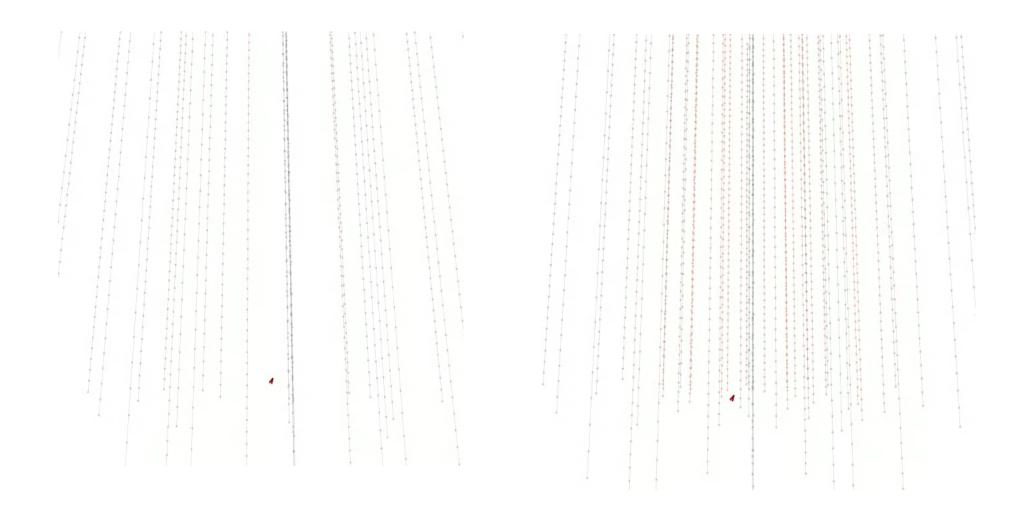
* 3000 per second

** 1 every 6 minutes



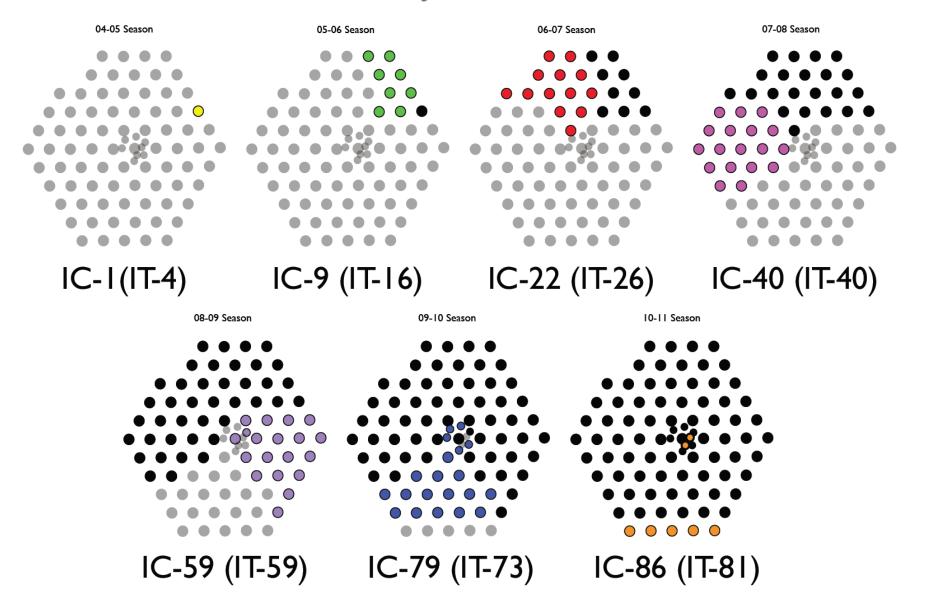
DeepCore (+6 strings):11 hits

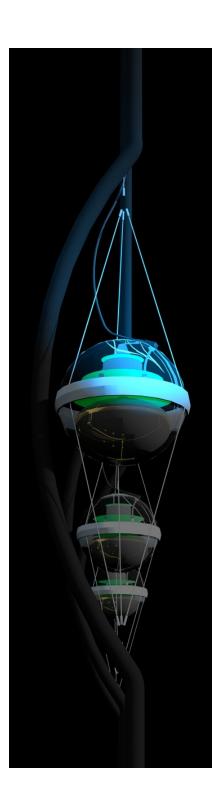
PINGU (+20 strings): 83 hits



8 GeV muon-neutrino

The IceCube Observatory

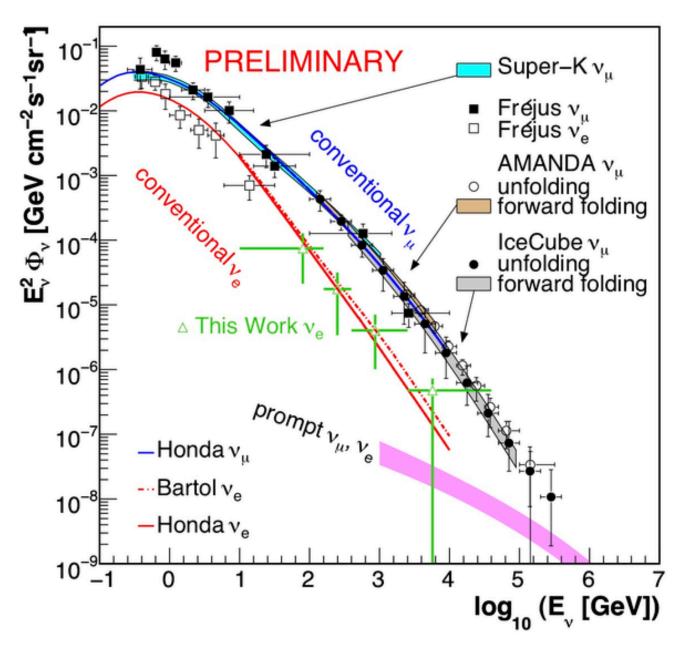




IceCube

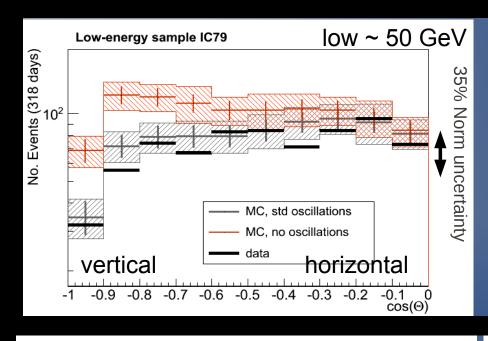
atmospheric and cosmic neutrinos

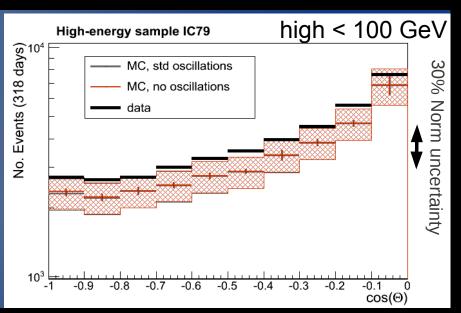
the search for dark matter

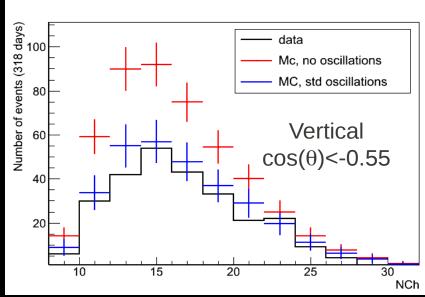


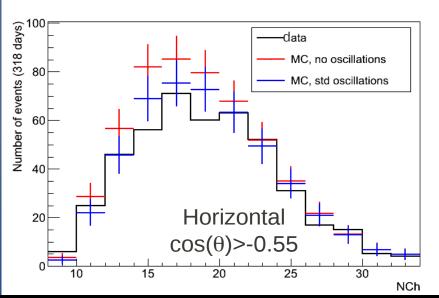
atmospheric neutrino spectrum to ~100 TeV

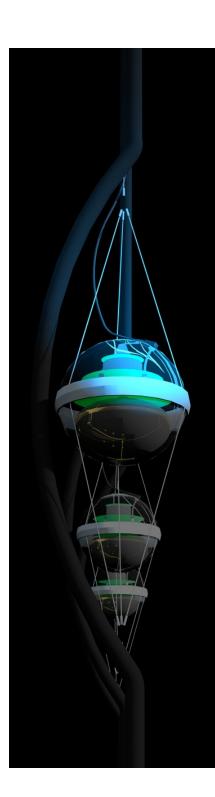
oscillations in DeepCore [5.6 sigma]











IceCube

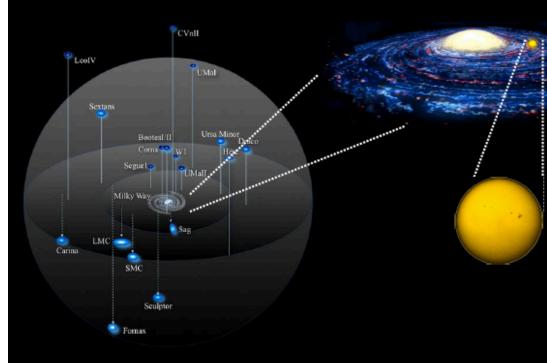
atmospheric and cosmic neutrinos

the search for dark matter

Indirect Search with IceCube



Look for potential sources that are well defined and have low or understood astrophysical backgrounds



Galactic Center & Halo:

Limits from IceCube-22

Galactic Center:

Limits from IceCube-40

Local sources:

Sun:

Combined Limits form AMANDA, IC22, IC40+AMANDA

→ IceCube-79 final sensitivity *new

Searches beyond "standard" SUSY:

→ secluded dark matter sector *new

Earth:

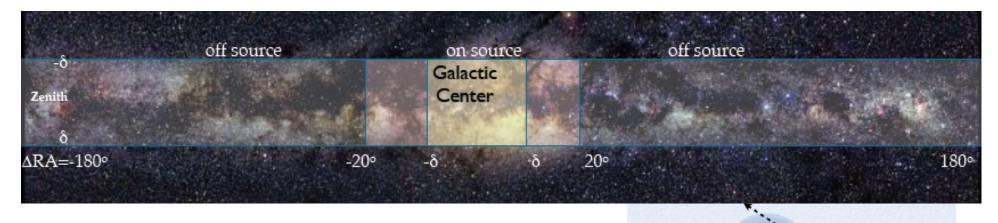
Limits from AMANDA (new analysis with IceCube-86 ongoing)

Dwarf spheroidal Galaxies:

→ IceCube-59 llmIts *new

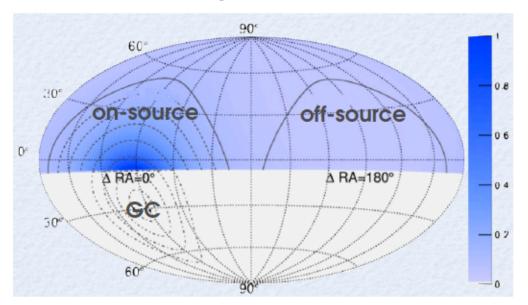
Clusters of Galaxies:

→ IceCube-59 llmlts *new



Galactic Center:

- x on-source region below the horizon
- x need to veto downgolng muons.
- x Use central strings of detector as flducial volume, surrounding layers as veto.



Observations in both analyses were consistent with background-only expectations

IC22 (Halo analysis - 275 days):

observed on-source: 1367 evts

observed off-source: 1389 evts

Event selection dominated by atm. ${f v}$

IC40 (G-Center analysis - 367 days):

observed on-source: 798842 evts

predicted from off-source: 798819 evts

Event selection dominated by atm. μ

Galactic & galaxy cluster limits



ICECUBE

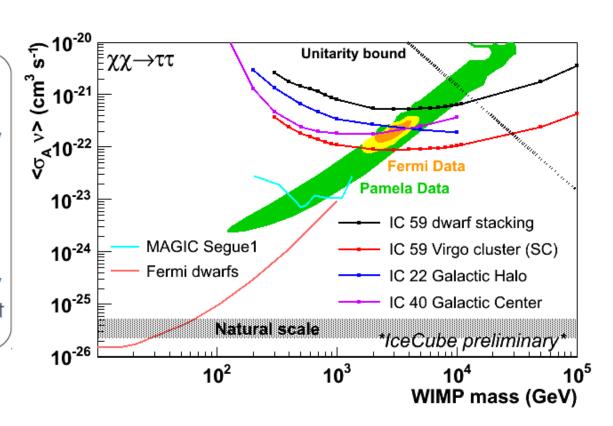
Limits computed at **90% C.L.** as function of WIMP mass and for various annihilation channels assuming branching fractions of 100%

Dwarf galaxies:

- Source stacking analysis
- Optimized size of search window
- NFW profile assumed

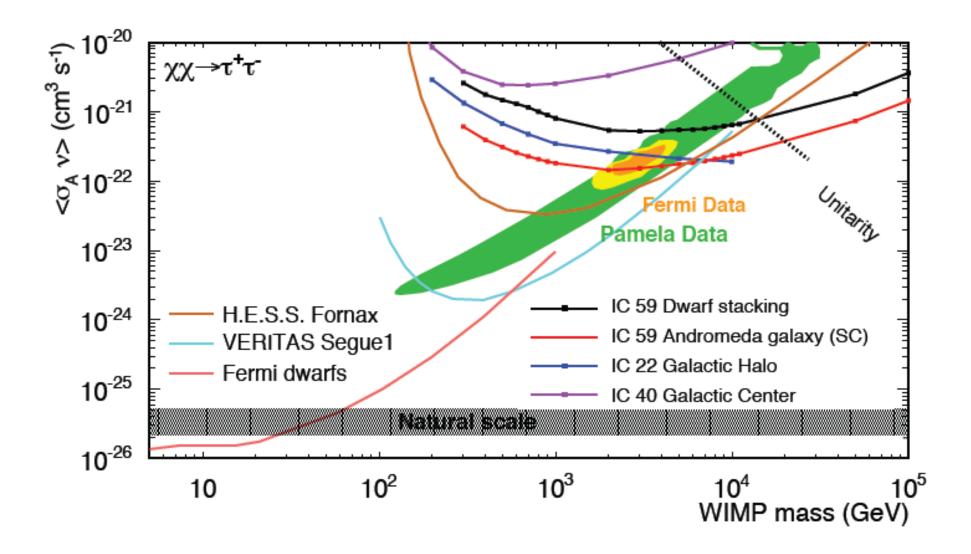
Galaxy clusters:

- Extended point source search
- Optimized size of search window
- Substructures taken Into account



multi-wavelength approach to dark matter searches:

IceCube can test DM models motivated by PAMELA & Fermi data (e.g. Meade et al. 2008)



WIMP Capture and Annihilation

- Halo WIMPs scatter on nuclei in the Sun
- Some lose enough energy in the scatter to be gravitationally bound
- Scatter some more, sink to the core
- Annihilate with each other, producing neutrinos
- Propagate+oscillate their way to the south pole, convert into muons in the ice

$$\chi + \chi \rightarrow W + W \rightarrow v + v$$
$$b + b \rightarrow v + v$$

$$\frac{dN_{\chi}}{dt} = C_{sun} = \phi_{\chi} \sigma_{sun}$$

$$\bullet \quad \phi_{\chi} = \left[\frac{\rho}{m_{\chi}}\right] \quad v_{\chi}$$

$$\bullet \ \sigma_{sun} = \frac{M_{sun}}{m_p} \, \sigma_{\chi}$$

•
$$C_{sun} = 2 C_{annihilation}$$

given a cross section and a branching ratio into neutrinos the model is seen or ruled out

indirect dark matter detection

- indirect rates are dictated by the interaction cross section of WIMPS with hydrogen.
 - no unknown astrophysics
- in the neutrino case there is a direct connection between theory and observation and the background is understood.

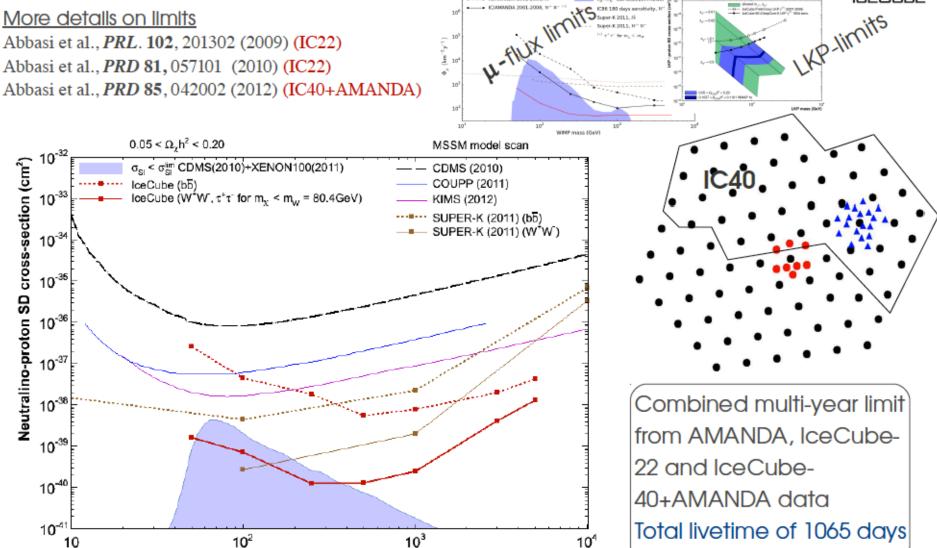
Analysis Results from the Sun



ICECUBE

More details on limits

Abbasi et al., PRL. 102, 201302 (2009) (IC22) Abbasi et al., PRD 81, 057101 (2010) (IC22)



Neutralino mass (GeV)

IceCube 79 string analysis







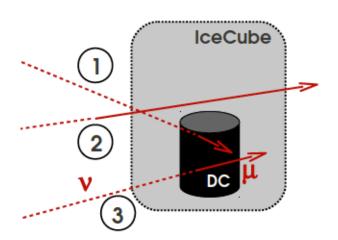
Solar WIMP analysis with 79 strings (sensitivity)

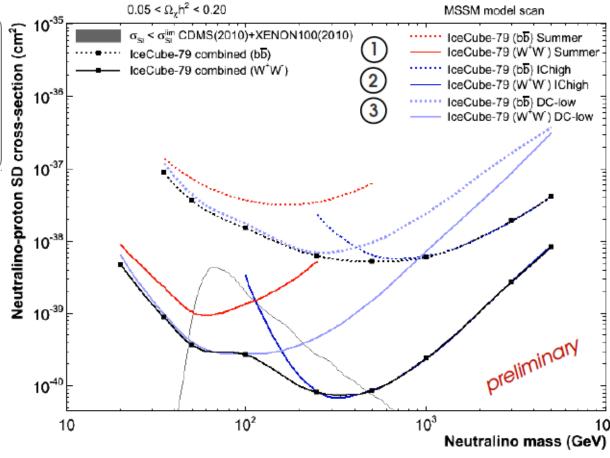
- Incl. DeepCore
- Performed separately for austral winter & summer (152d +167d livetime)
- Low energies (look for contained or partially contained events)

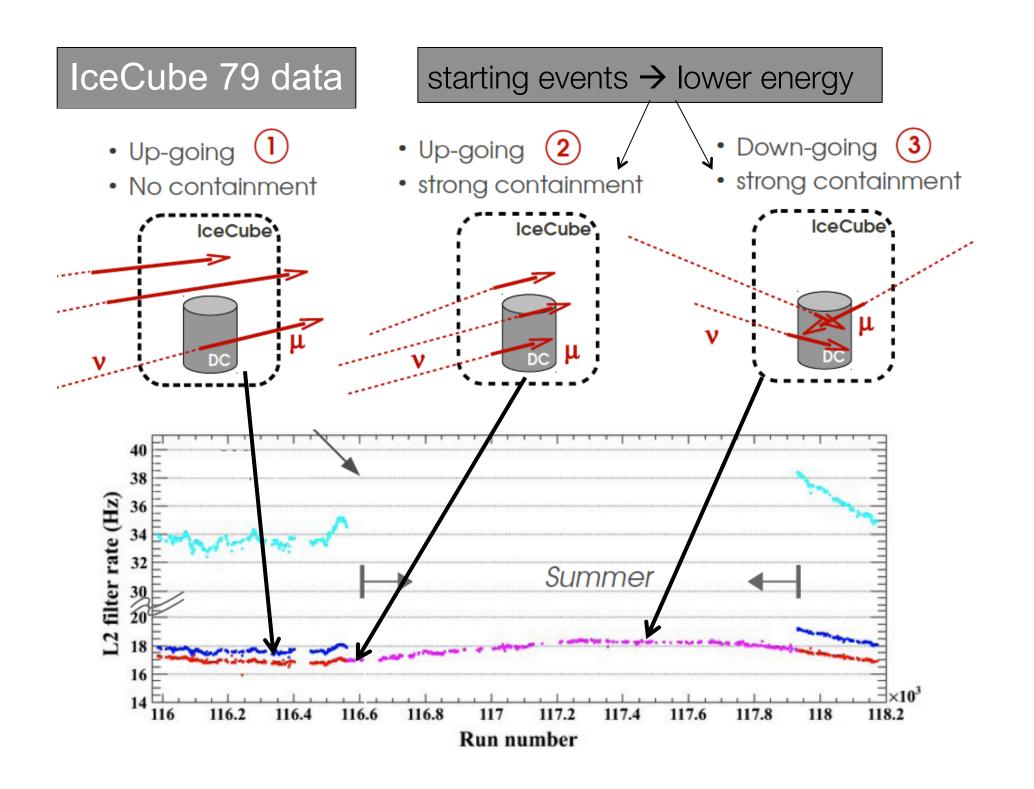
Analysis performed separately for; austral summer (Sun above horizon)

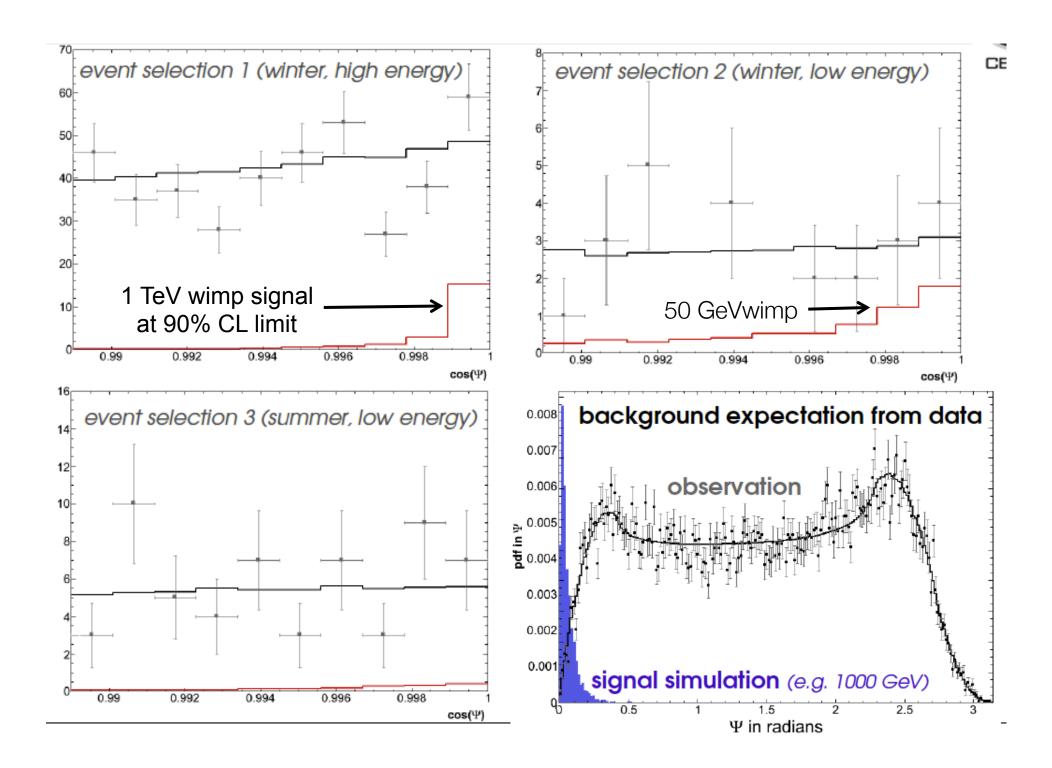
&

austral winter (Sun below horizon)



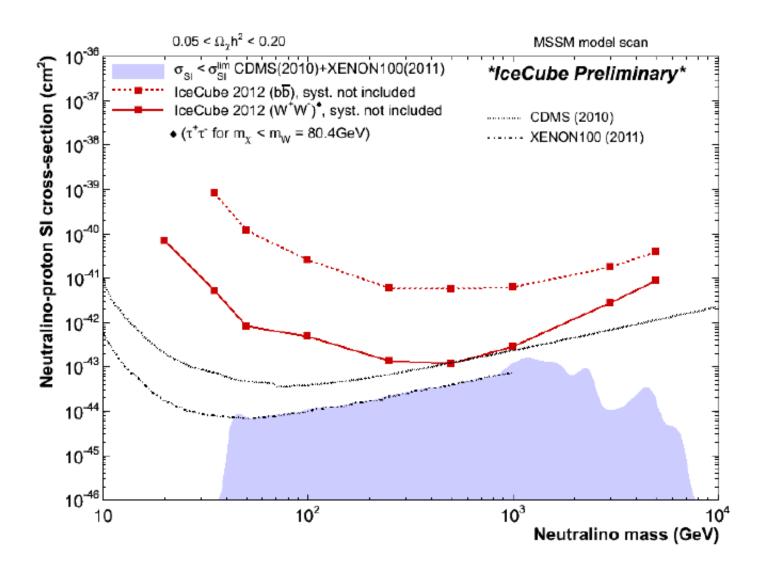






Unblinding results (SI-cross-section limit)

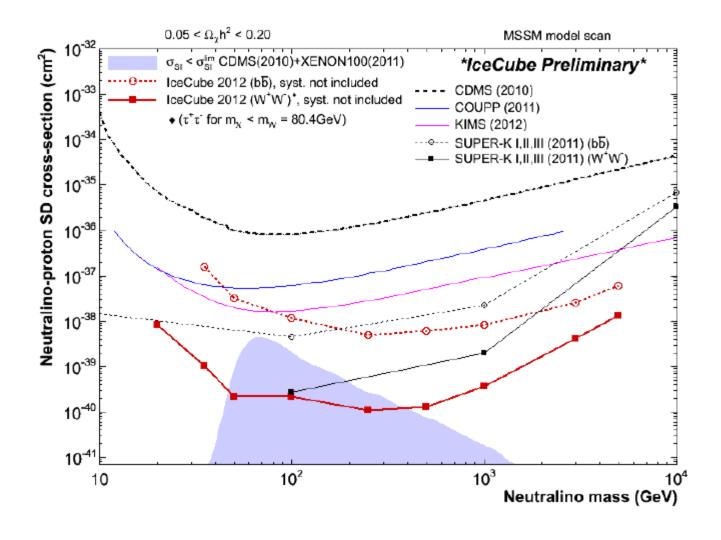




Unblinding results (SD-cross-section limit)

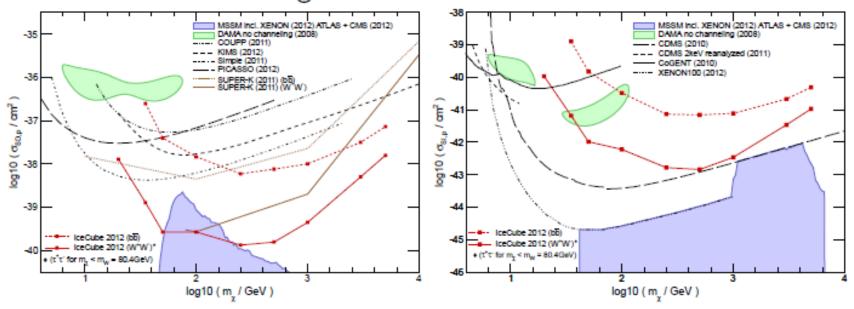






indirect dark matter detection in the sun

Dark Matter accumulates in the center of the sun – high-energy neutrino annihilation signatures from the sun



Threshold \sim 20 GeV

arXiv:1212.4097, accepted PRL

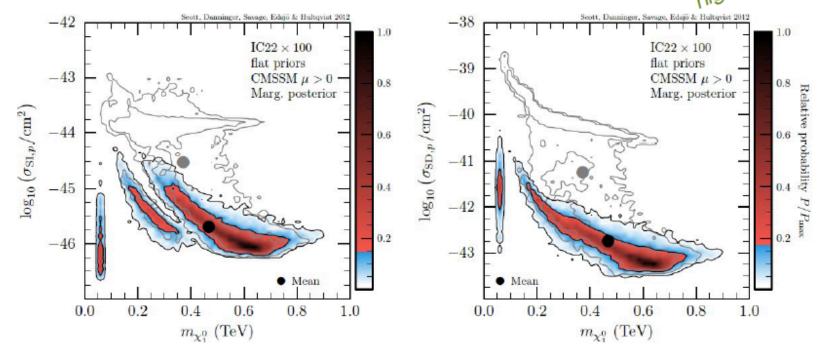
Global SUSY analysis with IceCube



More detalls: P.Scott, C.Savage, J. Edsjö & the IceCube Collaboration, arXiv:00001v1

CMSSM, IceCube-22 with 100x boosted effective area (indication for IceCube-79 and 86-string prospects)

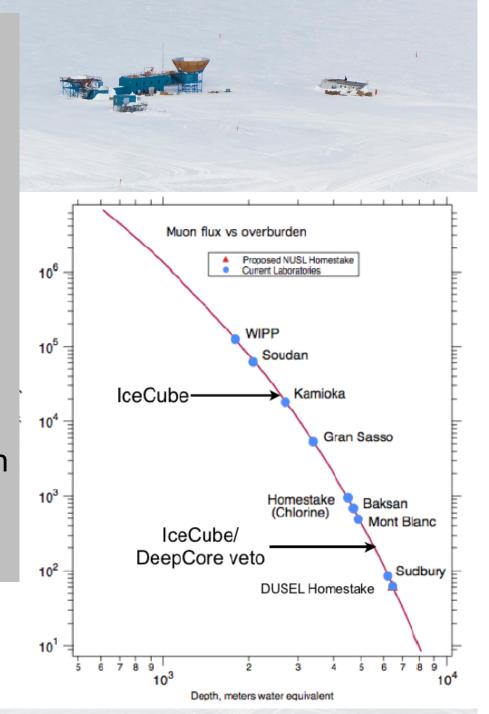
Plots will be plots with substituted with substituted with higher quality plots

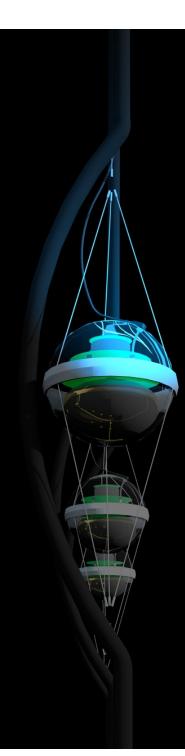


- X Contours indicate 1σ and 2σ credible regions
- X Grey contours correspond to fit without IceCube data
- * Shading+contours indicate *relative* probability only, not overall goodness of fit

IceCube drilling to best low background site on Earth:

- → radio-pure ice
- → no seasonal variations (temperature, humidity,...)
- → shielded from cosmic rays by IceCube veto
- DM-ice, DeepCore upgrades
- \$1.25M per string of 60 ten inch PMTs (data to your pc, includes logistics





all results with detector under construction

- soon:
 - → results from completed detector with improved software and calibration
 - → WIMP masses as low as 10 GeV
- far from the square root regime
- thanks: C. Rott, D. Grant and M. Danninger

The IceCube Collaboration



International Funding Agencies

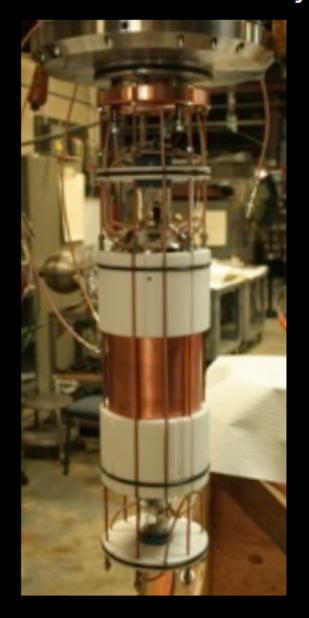
Fonds de la Recherche Scientifique (FRS-FNRS) Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)

Federal Ministry of Education & Research (BMBF)

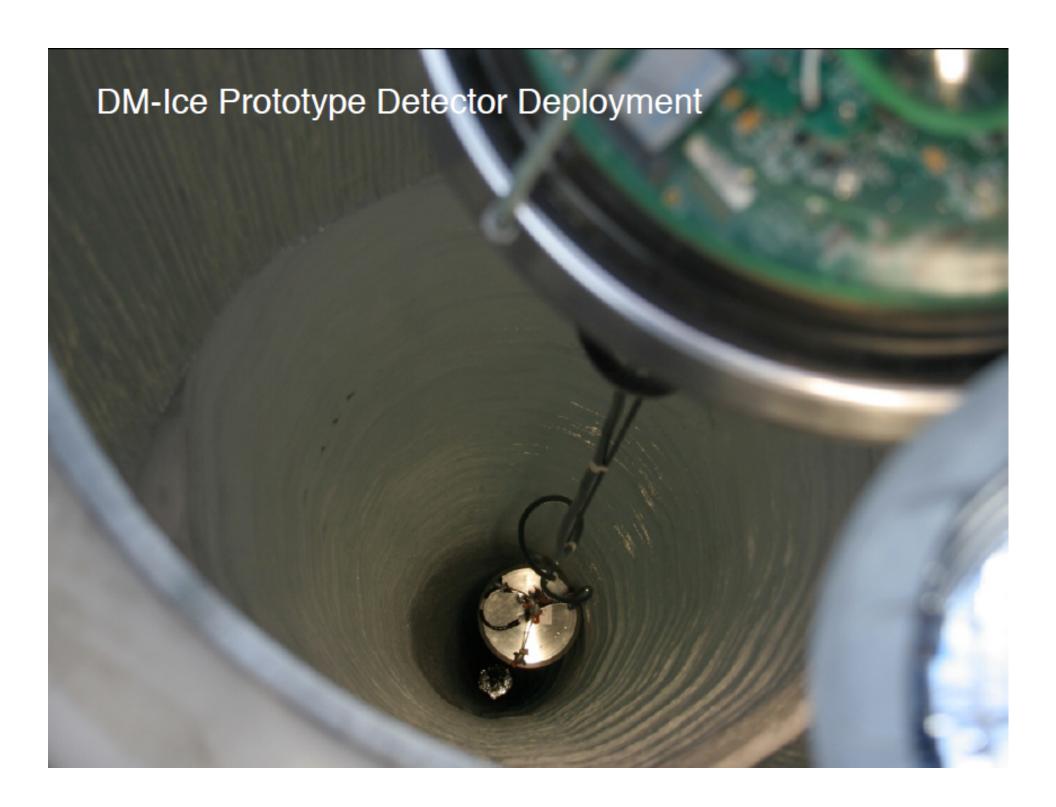
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat

The Swedish Research Council (VR)
University of Wisconsin Alumni Research
Foundation (WARF)
US National Science Foundation (NSF)

DM-Ice Prototype Detector



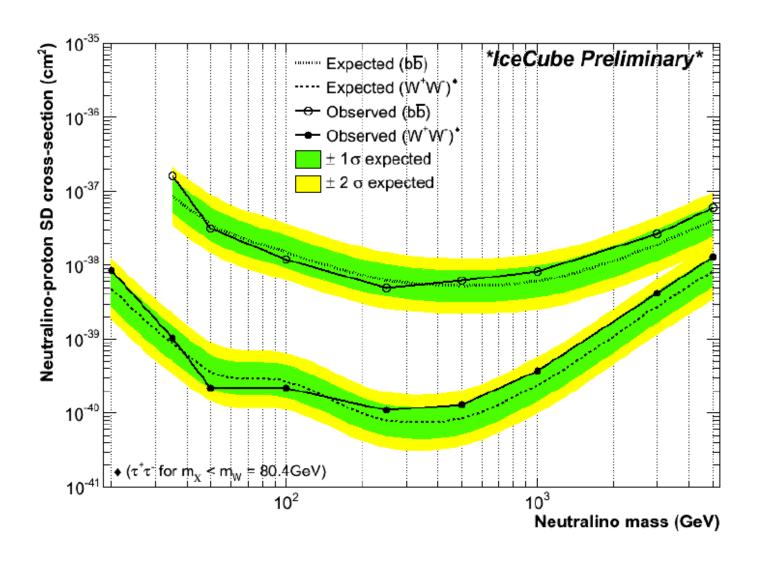




Unblinding results (observed results)







IceCube 79 string sensitivity



ICECUBE

Sensitivity extends to WIMP masses of 20 GeV

Only 1 year of data

Data unblinding soon!

also search for UED models (not shown here)

